An Effects-based Assessment of Numeric CHLa Criteria for the James Estuary

Prepared by the Science Advisory Panel
for VA Department of Environmental Quality
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DEQ Science Advisory Panel

- Question: Are current numeric CHLa criteria for the tidal James scientifically defensible?
  - Specifically, are criteria protective of aquatic life designated uses?
- Task: analyze available data to characterize effects of algal blooms in the James (empirical, effects-based approach).
  - Report completed and submitted to DEQ (August 2015). Currently undergoing agency review.

An Effects-Based Approach

- Advantages
  - Establishes quantitative linkages between algal blooms (CHLa) and harmful effects on aquatic life.
  - Quantifies benefits of attaining criteria in the context of minimizing harmful effects for each season and segment.
- Limitations
  - Considers only those effects which are apparent from the available data.

Conceptual Issues

What do we mean by ‘protective’, ‘defensible’?

- Ideally, criteria should mitigate deleterious effects of algal blooms (low DO, HABs, etc.).
- Criteria that are ‘protective’ will, at attainment, minimize deleterious effects.*
- Criteria that are ‘defensible’ will be neither under-protective (failing to mitigate deleterious effects), nor over-protective (falling below the range where further benefits accrue).

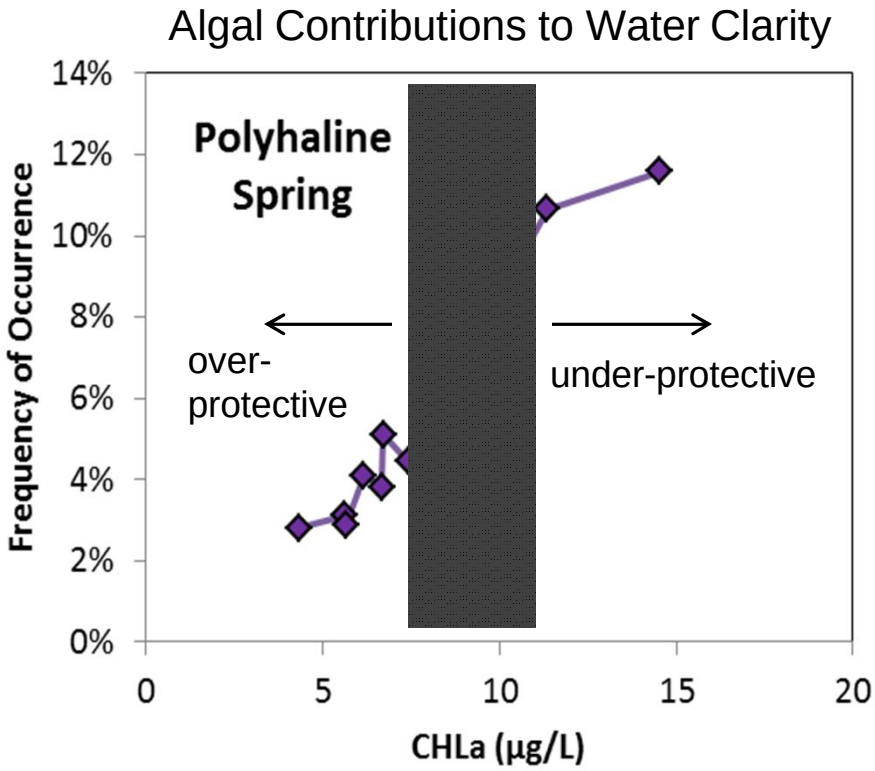
*It is recognized that attainment of CHLa criteria alone may not fully restore designated uses (e.g., poor water clarity due to non-algal particulate matter).

Conceptual Issues

Example: the frequency with which algal contributions to water clarity exceed a specified threshold increases in relation to mean CHLa.

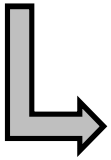
CHLa criteria falling within the shaded range would be considered defensible as being neither over- nor under-protective.

The span of this range reflects uncertainty in the relationship based on the distribution of available data.



Empirical Approach

- What are the threats to aquatic life designated uses posed by algal blooms?
  - Objective 1: identify metrics and data sources (e.g., DO, pH, water clarity, phytoplankton IBI, HABs).
- Are metrics responsive to CHLa?
  - Objective 2: relate probability of exceeding thresholds to CHLa.
- Are current CHLa criteria protective?
  - Objective 3: assess probability of exceeding thresholds over a range of mean CHLa.



What is the expected frequency of threshold exceedance at attainment of current CHLa criteria?

Data Used for this Analysis

Source	Segment	Frequency	Stations	Duration
DEQ-CBP	All	Monthly	12	1985-2013
VIMS	All	Continuous	5	2006-2008
VCU	TF	Weekly	12	2010-2014
HRSD	OH,MH,PH	Weekly	Continuous	2005-2013

Observations	Candidate Metrics
Monthly, long-term	Water clarity, PIBI
Continuous, fixed station*	DO, pH
Weekly, tidal fresh	*Microcystis*, microcystin
Weekly, dataflow*	*Cochlodinium*, evenness

*sensor-based data converted to ‘extracted equivalents’

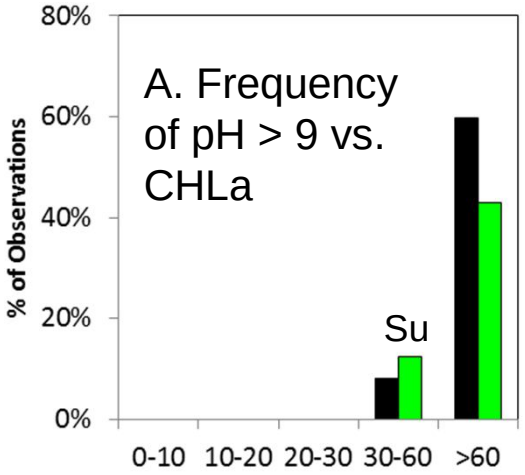
Metrics and Results

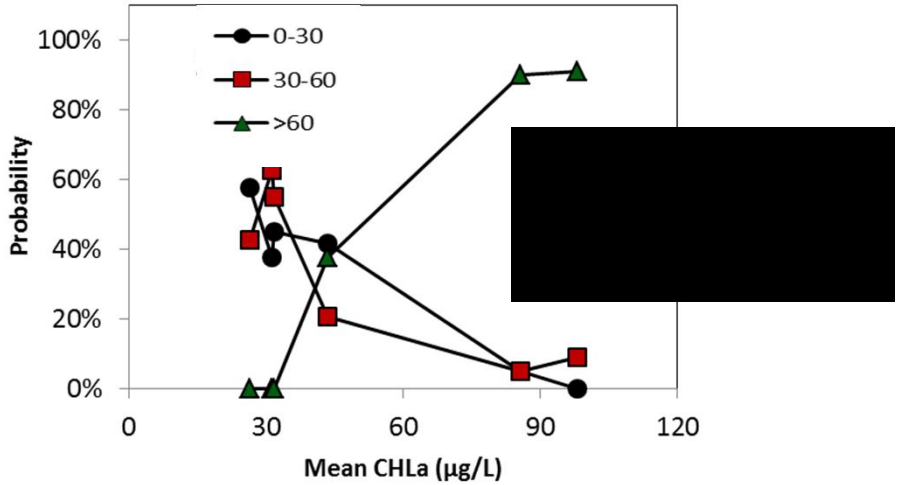
- Water quality
  - Daily minimum (10%-tile) DO < 5 mg/L
  - Daily maximum (90%-tile) pH > 9
- Water clarity
  - algal biomass > 10% TSS
- Phytoplankton
  - PIBI>2.67 ('least degraded')
- HAB metrics
  - TF: *Microcystis* > 20k cells/ml; microcystin >0.8 µg/L
  - OH, MH & PH: *Cochlodinium* >1,000 cells/ml

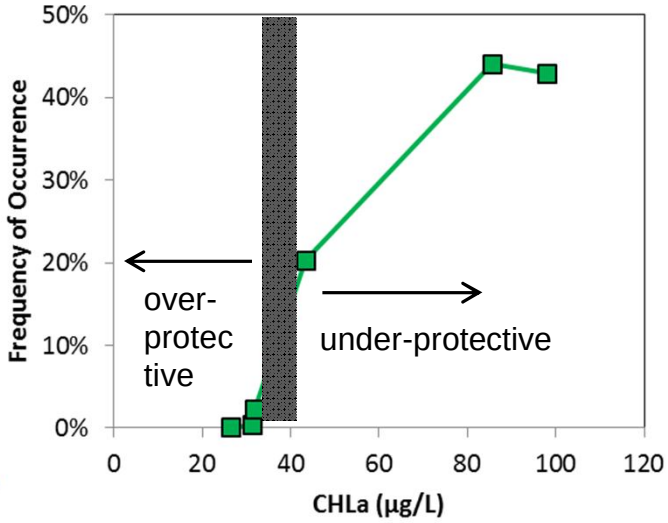
Segment	Metric	Season
TF-up	Microcystin	Summer
TF-low	pH	Spring, Summer
	Clarity	Summer
	PIBI	Spring, Summer
	Microcystin	Summer
OH	pH	Spring
	PIBI	Spring
MH	pH	Spring
	DO	Summer
	Evenness	Spring, Summer
	Cochlodinium	Summer
PH	Clarity	Spring
	Evenness	Spring, Summer
	Cochlodinium	Summer

Table 4. Indicator metrics showing relationships to CHLa by segment and season.

Sample Results: Summer pH (Tidal Fresh)

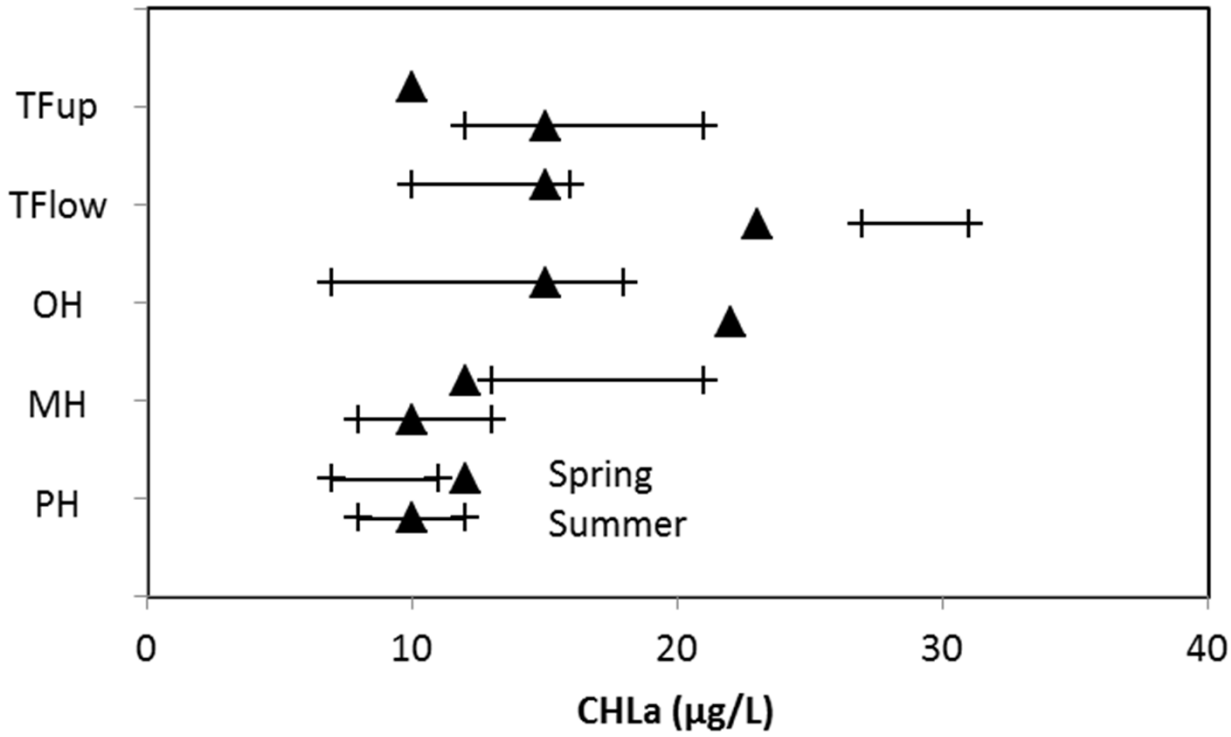






C. Combined frequency distribution: occurrence of daytime pH maxima >9 in relation to summer mean CHLa.

Substantive Findings



Current CHLa criteria (symbols) and proposed protective range (horizontal lines) of CHLa by season and segment.

Substantive Findings

Segment	Season	Current Criteria	Defensible Range	Are current criteria protective?
TF-up	Spring	10	None	
	Summer	15	12-21	Yes
TF-low	Spring	15	10-16	Yes
	Summer	23	27-31	Yes (over)
OH	Spring	15	7-18	Yes
	Summer	22	None	
MH	Spring	12	13-21	Yes (over)
	Summer	10	8-13	Yes
PH	Spring	12	7-11	No (under)
	Summer	10	8-12	Yes

SUPPLEMENTARY INFORMATION

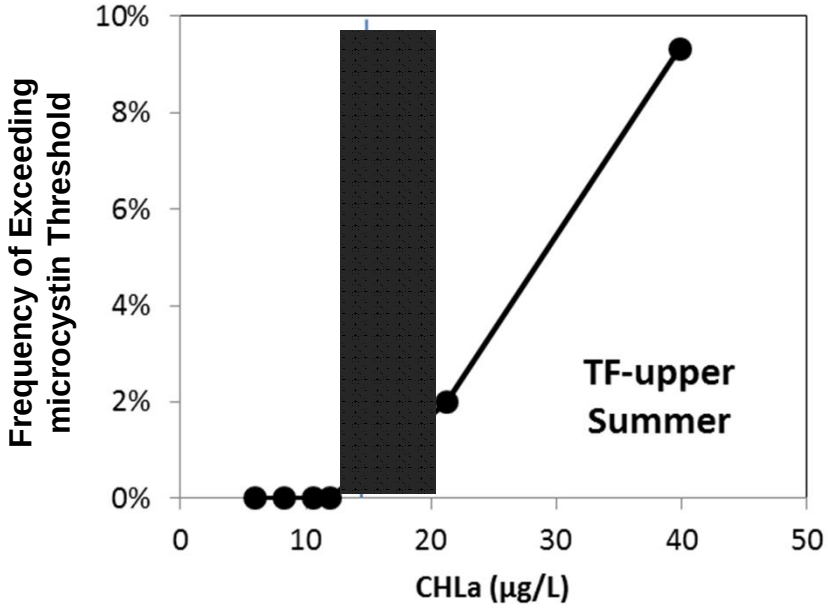
Segment-specific Findings

Data Used for this Analysis

Empirical Approach

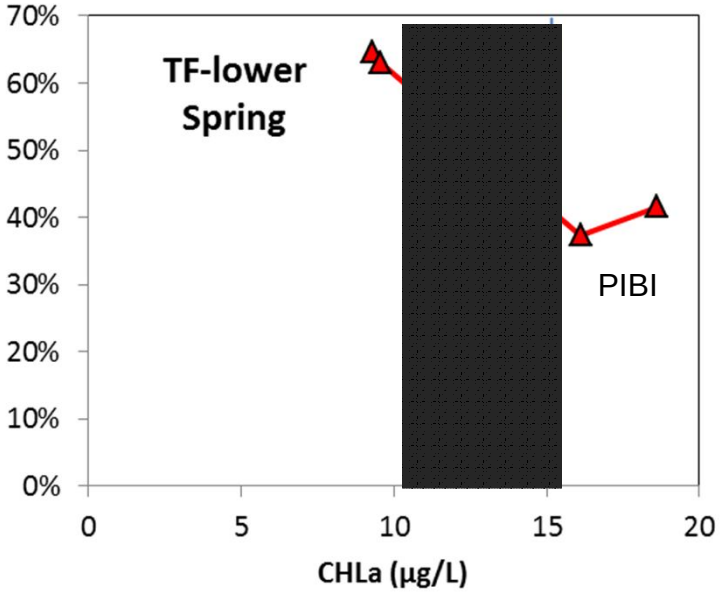
- Define metrics and thresholds of concern (e.g., DO < 5 mg/L; pH > 9).
- Calculate the probability of exceeding thresholds for observations pooled within CHLa ranges (e.g., 0-10, 10-20 µg/L).
- Derive combined probability of exceeding threshold at a given CHLa, and probability of occurrence for that CHLa over a range of mean CHLa values.
- Define range of mean CHLa considered protective; compare to current criteria.

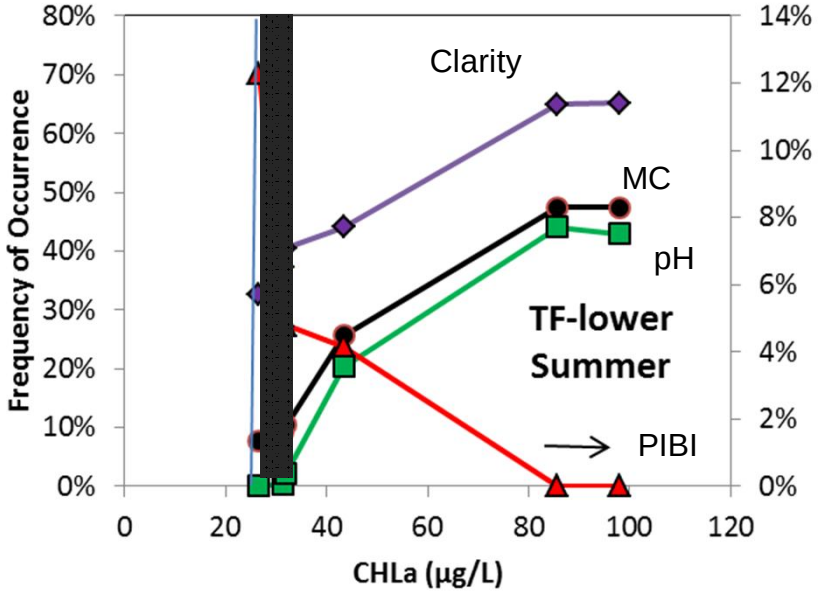
Upper Tidal Fresh



Upper TF	Spring	Summer
Current Criteria	10	15
Metrics ($p<0.05$)	None	microcystin
Defensible Range	NA	12-21

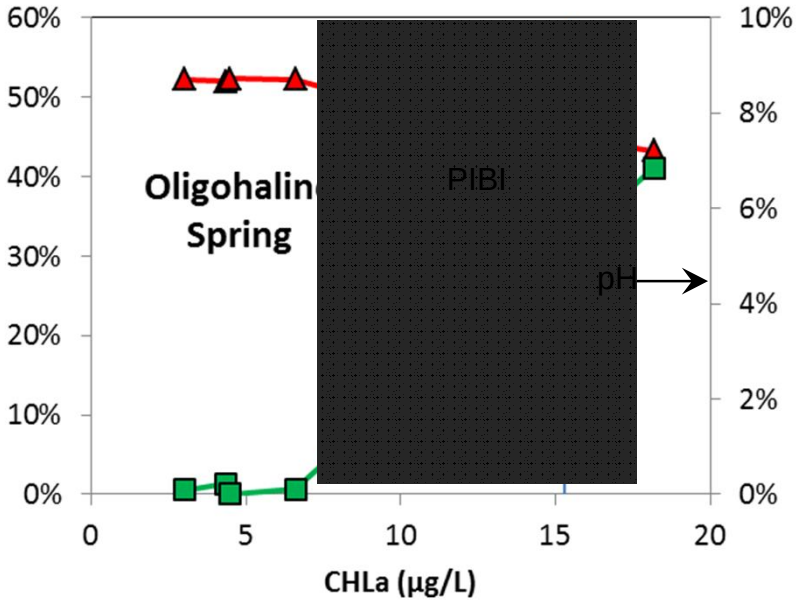
Lower Tidal Fresh





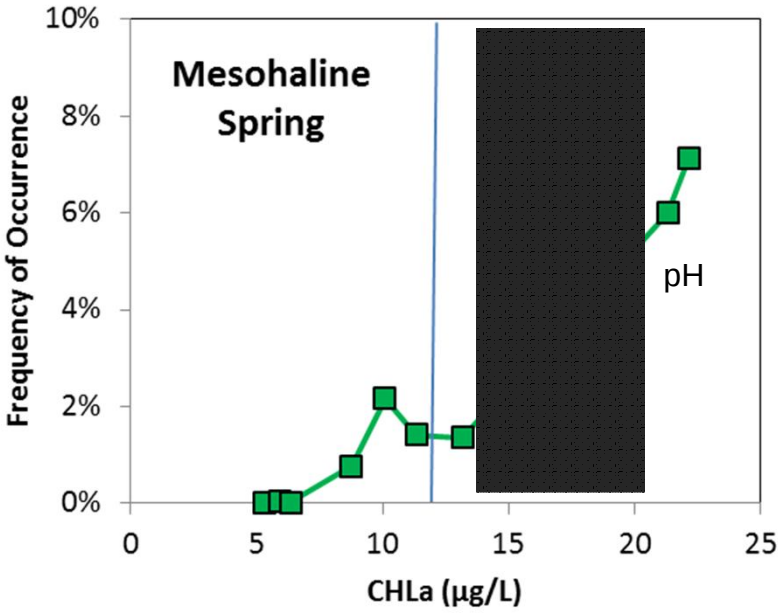
Lower TF	Spring	Summer
Current Criteria	15	23
Metrics (p<0.05)	PIBI	Clarity, MC, pH, PIBI
Defensible Range	10-16	27-31

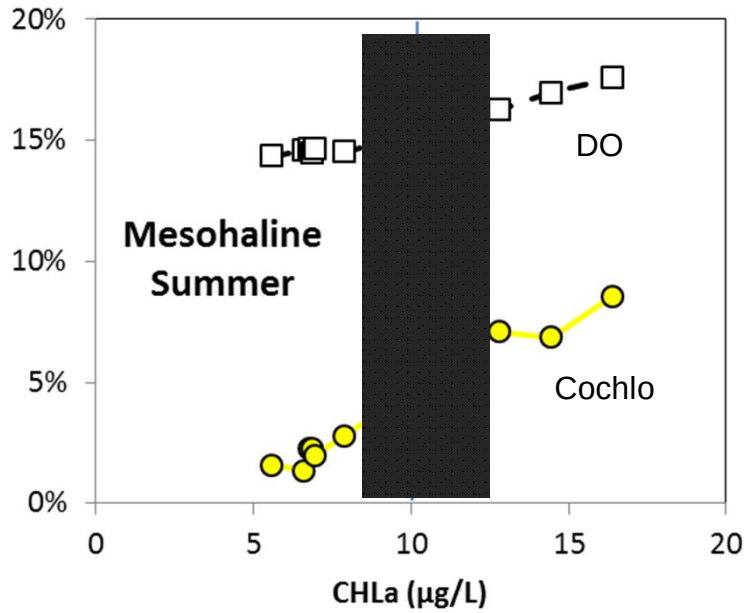
Oligohaline



Oligohaline	Spring	Summer
Current Criteria	15	22
Metrics ($p<0.05$)	PIBI, pH	None
Defensible Range	7-18	NA

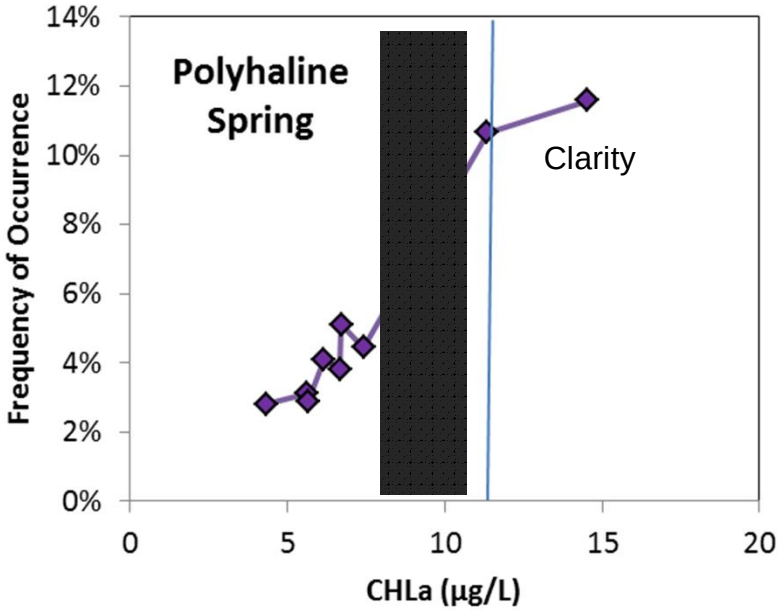
Mesohaline

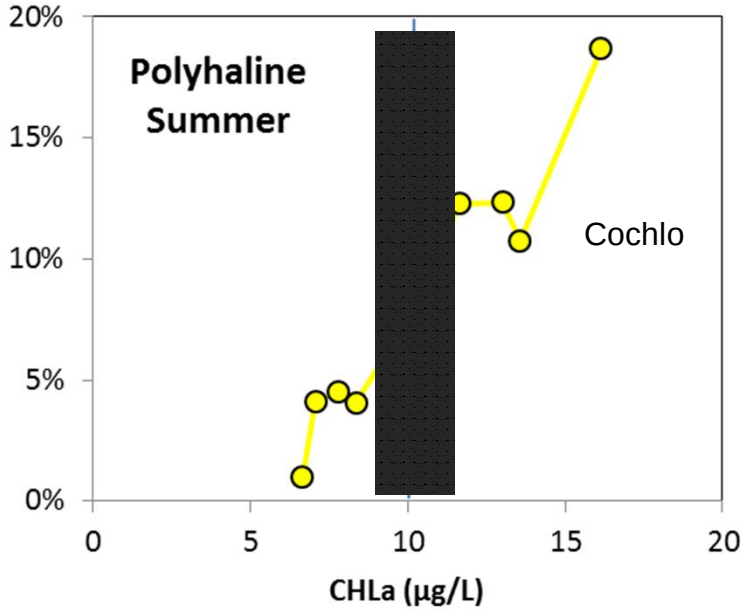




Mesohaline	Spring	Summer
Current Criteria	12	10
Metrics ($p<0.05$)	pH	DO, Cochlo
Defensible Range	13-21	8-13

Polyhaline





Polyhaline	Spring	Summer
Current Criteria	12	10
Metrics (p<0.05)	Clarity	Cochlo
Defensible Range	7-11	8-12

Data Used for this Analysis

Paramater	Metric & Threshold	Period	Segment	Data & Source
CHLa	Seasonal and segment-specific means compared to current criteria	2009-2014	TF1, TF2, OH, MH, PH	Weekly fixed-station monitoring (TF1, TF2; VCU); weekly spatially continuous monitoring (OH,MH,PH; HRSD)
Dissolved Oxygen (DO)	Daily minima (10%-tile) < 5 mg/L	2006-2008	TF1, TF2, OH, MH, PH	Continuous fixed station monitoring (VIMS)
pH	Daily maxima (90%-tile) > 9	2006-2008	TF1, TF2, OH, MH, PH	Continuous fixed station monitoring (VIMS)
Water Clarity	Percent Light through Water (PLW> 13%, 23%,)	2006-2013	OH, MH, PH	CHLa, turbidy & salinity from dataflow cruises (VIMS, HRSD)
	Algal contributions to TSS > 20%	1985-2013	TF2, OH, PH	Monthly phytoplankton counts & TSS (CBP)
Phytoplankton	Community multimetric indices (PIBI>2.67)	1985-2013	TF2, OH, PH	Monthly phytoplankton counts (CBP)
	Community diversity & eveness	2011-2013	OH, MH, PH	Phytoplankton sampling during dataflow cruises (HRSD, ODU)
	HAB (Microcystin > 0.8 µg/L)	2011-2014	TF1, TF2	Weekly monitoring of Microcystin (VCU)
	HAB (*Microcystis* > 20k cells/ml)	1985-2014	TF1, TF2	Monthly (1985-2013) and weekly (2011-2014) phytoplankton counts (ODU)
	HAB (*Cochlodinium* > 1,000 cells/ml)	2011-2014	OH, MH, PH	Phytoplankton sampling during dataflow cruises (HRSD, ODU)